LINDSTROM

Design of a Hydraulic Shaft-Straightening Machine

Mechanical Engineering

B. S.

1911

DESIGN OF A HYDRAULIC SHAFT-STRAIGHTENING MACHINE

BY

ARTHUR WILLIAM LINDSTROM

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

UNIVERSITY OF ILLINOIS

May 31 1911

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Arthur William Lindstrom

ENTITLED Design of a Hydraulic Shaft-Straightening Machine

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

W. D. Dunkin
Instructor in Charge

APPROVED: G. A. Goodenough

HEAD OF DEPARTMENT OF

DESIGN OF A HYDRAULIC

SHAFT STRAIGHTENING MACHINE

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Specifications

Maximum pressure on piston — 75 tons

Unit pressure — 2000 pounds per square inch

Total movement of piston — 4 inches

Diameter of piston — 10 inches

Capacity of machine- (fibre stress 50000 pounds)

6 1/8 inch shaft on 30 inch centers

6 3/4 " " " 40 " "

7 1/8 " " " 48 " "

7 3/4 " " " 60 " "

Pump- Double cylinder, single acting, 3/4 inch diameter, 1 1/2 inch stroke

Floor space- 12 feet by 3 feet

Maximum height- 6 feet

Calculations

Symbols used

M = bending moment

I = moment of inertia

c = distance from most remote fibre to gravity axis

S = working stress

d = diameter of section

p = unit pressure

P = total pressure

C = constant determined experimentally

F = friction

E = efficiency

t = thickness

r = radius

r_1 = inside radius

r_2 = outside radius

b = breadth

A. Piston

Total pressure - 75 tons

Unit pressure - 2000 pounds per square inch

$\frac{75 \times 2000}{2000}$ = 75 square inches- area of piston

Diameter corresponding = 9 13/16 say 10 inches

Pressure exerted by 10 inch piston =

78.65 x 2000 = 157000 pounds

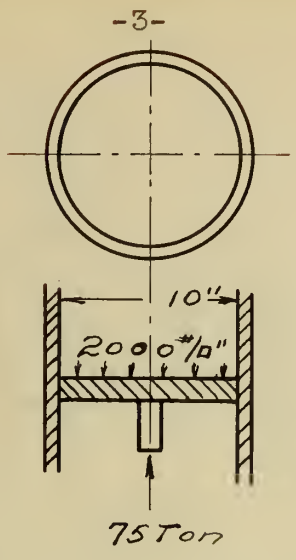


Fig. 1.

Efficiency of piston = $\frac{\text{Total Pressure - Friction}}{\text{Total Pressure}} 100$

$$E = \frac{\pi d^2 p/4 - F}{\pi d^2 p/4} 100$$

F = Cpd — Hicks' formula(American Machinist- Sep. 22, 1910)

Therefore

$$E = 1 - \frac{4F}{\pi d^2 p} 100 = 1 - \frac{4Cpd}{\pi d^2 p} 100$$

$$= 1 - \frac{4C}{\pi d} 100$$

C varies from .0314 to .047 for different packings

Let C = .04

$$E = 1 - \frac{4 \times .04}{\pi \times 10} 100$$

$$= (1 - .00509)\,100$$

$$= 99.491$$

Force transmitted by piston

$$= 157000 \times .99491 = 156000$$

B. Piston Head

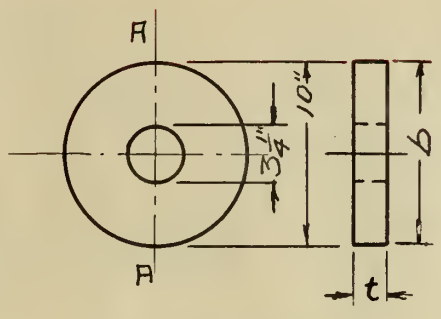


Fig. 2.

Bending moment at section "A A"

$M = pA \times r \qquad r = .212\ D$

$= 2000 \times \frac{\pi 10^2}{2 \times 4} \times 2.12$

$= 159{,}000$ inch pounds

Use steel with unit stress of 16000 pounds per square inch

$\frac{I}{c} = \frac{M}{S} = \frac{159000}{16000} = 9.95$

$bt^2/6 = 9.95$

$b = 10''$

$t^2 = 7.8$

$t = 2.8$ say 3 inches

C. Piston Rod

Use cold rolled steel- S = 18000 pounds per square inch

$\frac{P}{S} = A$

$\frac{150000}{18000} = 8.34$ square inches

Diameter = 3.3 say 3 1/2 inches

D. Cylinder Walls

Use cast steel S = 10000 pounds per square inch

Lames' formula for thick cylinders (Merriman- Mechanics of Materials- p. 305)

$$r_2 = r_1\sqrt{\frac{S + p}{S - p}}$$

$$= 5\sqrt{\frac{10000 + 2000}{10000 - 2000}}$$

$$= 6.12$$

Therefore t = 1 1/8 inches

Clavarinos' formulae for thick cylinders (Merriman- Mechanics of Materials- p. 392)

$$r_2 = r_1\sqrt{\frac{3S + p}{3S - 4P}}$$

$$= 5\sqrt{\frac{3 \times 10000 + 2000}{3 \times 10000 - 4 \times 2000}}$$

$$= 6.03$$

t = 1 1/8 inches

E. Cylinder Head

Use Merriman's formula (p.409- Merriman's Mechanics of Materials) for plate uniformly loaded and supported around edge.

$$t = r\sqrt{\frac{2p}{3S}}$$

$$= 5\sqrt{\frac{2 \times 2000}{3 \times 10000}}$$

$$= 1.825$$

$$= 1\ 7/8 \text{ inches}$$

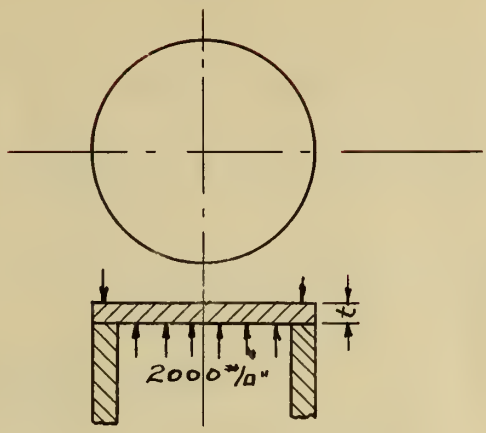


Fig. 3.

F. Stud Bolts for Cylinder Head

12000 pounds per square inch = unit stress of bolts

$\frac{150000}{12000}$ = 12.5 or total area of bolts

Net area of 1 1/4 inch bolt = .894

12.5/.894 or 16-1$\frac{1}{4}$inch stud bolts used.

G. Pinion to Raise Piston

Use 1 inch circular pitch, 10 teeth, pitch diameter = 3.183", 3/4 inch face

H. Side Rod

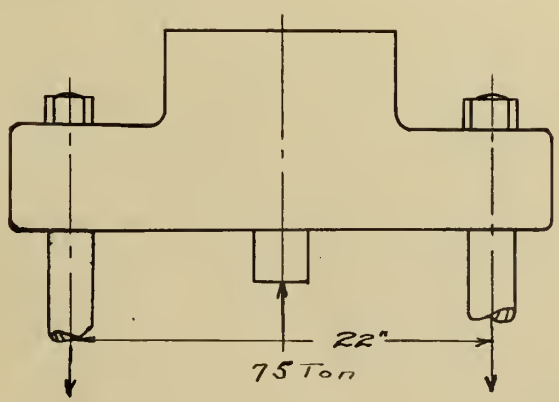


Fig. 4.

Assume 2/3 load supported on one rod

Tensile strength 16000 pounds per square inch

$$\frac{2}{3} \times \frac{150000}{16000} = 6.25 \text{ square inches net area}$$

Net diameter = 2 7/8 inches nominal diameter $3\frac{1}{4}$"

I. Side Rod Supports

Investigate for shearing

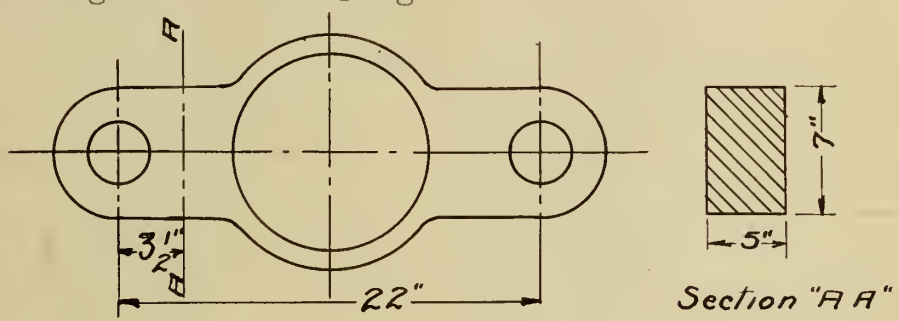


Fig. 5.

$$\frac{2}{3} \times 150000 \times \frac{1}{20000} = 5 \text{ square inches}$$

Total area 35 square inches

Investigate for bending

M = 2/3 x 150000 x 3.5 = 350000 in.lb.

$$\frac{M}{S} = \frac{I}{c} = \frac{350000}{16000} = 21.9$$

$\frac{I}{c}$ for section "A A" = $1/6 \times 7 \times 5^2 = 29.15$

J. Pump

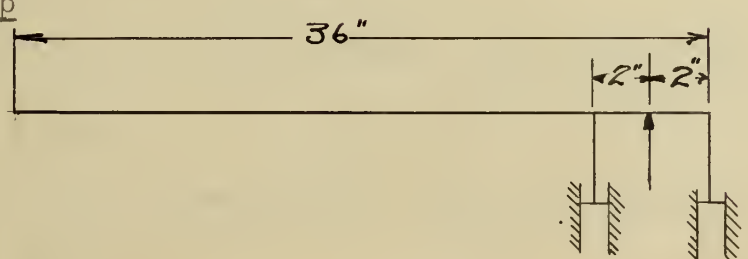


Fig. 6.

Use double cylinder single acting pump

Diameter of plungers 3/4 inch- stroke 1 1/2 inches

Pressure on plunger = $\pi(.75)^2/4 \times 2000 = 884$ pounds

Ratio of arms 1 to 18

Pressure to be exerted by man = 884/18 = 50 pounds

K. Pump Handle

M = 50 + 25 (for friction) 34 = 2550 pound-inches

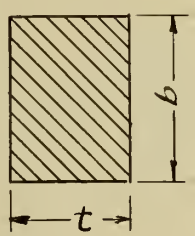


Fig. 7.

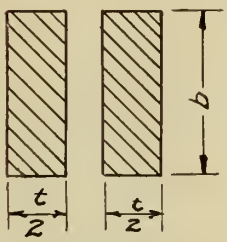


Fig. 8.

$$\frac{2550}{1200} = .2125 = \frac{I}{c} = \frac{b^2t}{6}$$

Let b = 1 1/4 then $b^2 = 1.565$

t = .2125 x 6/1.562

= .817 say 7/8 inch.

L. Tank

Volume of tank = stroke of piston x area of piston

= 4 x 78.6 = 314.4 cubic inches

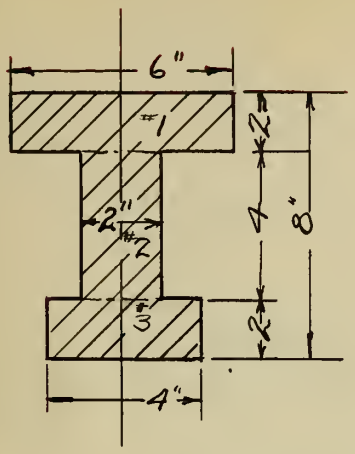
Adding 50% volume becomes 468 cubic inches

Dimensions of tank 6x6x13 = 468 cubic inches

M. Cross Beam

M = 75000 x 7 = 525000 inch pounds

$$\frac{I}{c} = \frac{525000}{10000} = 52.5$$



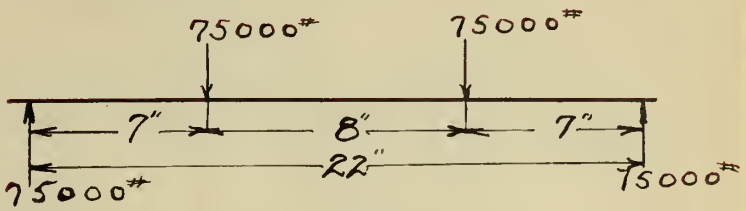


Fig. 10.

Fig. 9.

Section	Area	Mom. Arm	Mom.	c	I_{cg}	h	Ah^2	I	$\frac{I}{c}$
1	12	1	12		2	2.57	79.1	81.1	
2	8	4	32	3.57	3.62	.43	1.45	5.12	50.8
3	8	7	56		133	3.43	94	95.33	
	28		100					181.55	

N. Support Pins

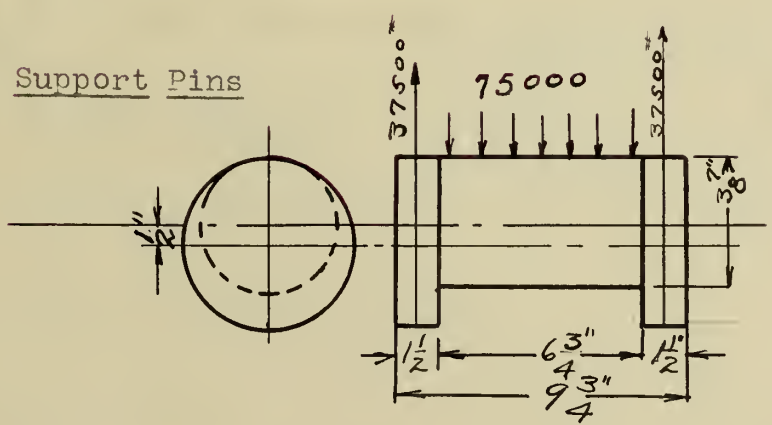


Fig. 11.

M = 37500 x 4 1/8 - 37500 x 1 11/16

= 91400 inch pounds

$\frac{M}{S} = \frac{91400}{16000} = 5.71$

Diameter = 3 7/8 inches

Area of pin = 11.8

$\frac{37500}{11.8}$ = 3180 pounds per square inch shearing stress

$\frac{37500}{1\frac{1}{2} \times 3\frac{7}{8}}$ = 6470 pounds per square inch bearing stress

Use 1/2 inch eccentricity

O. "I" Beams

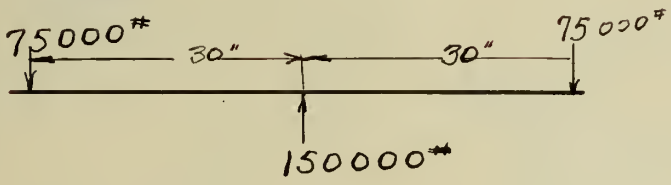


Fig. 12.

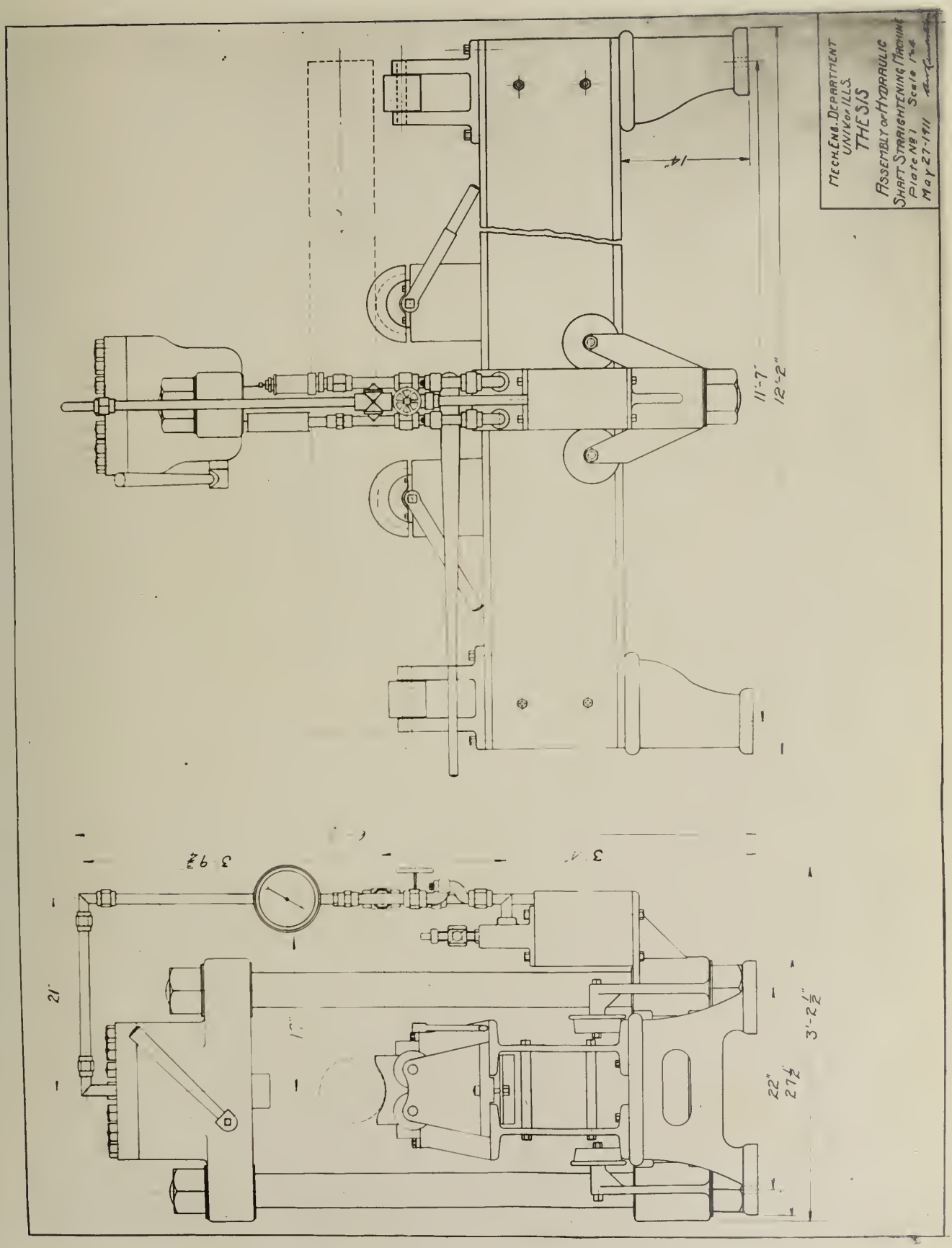
Maximum distance between supports when bending

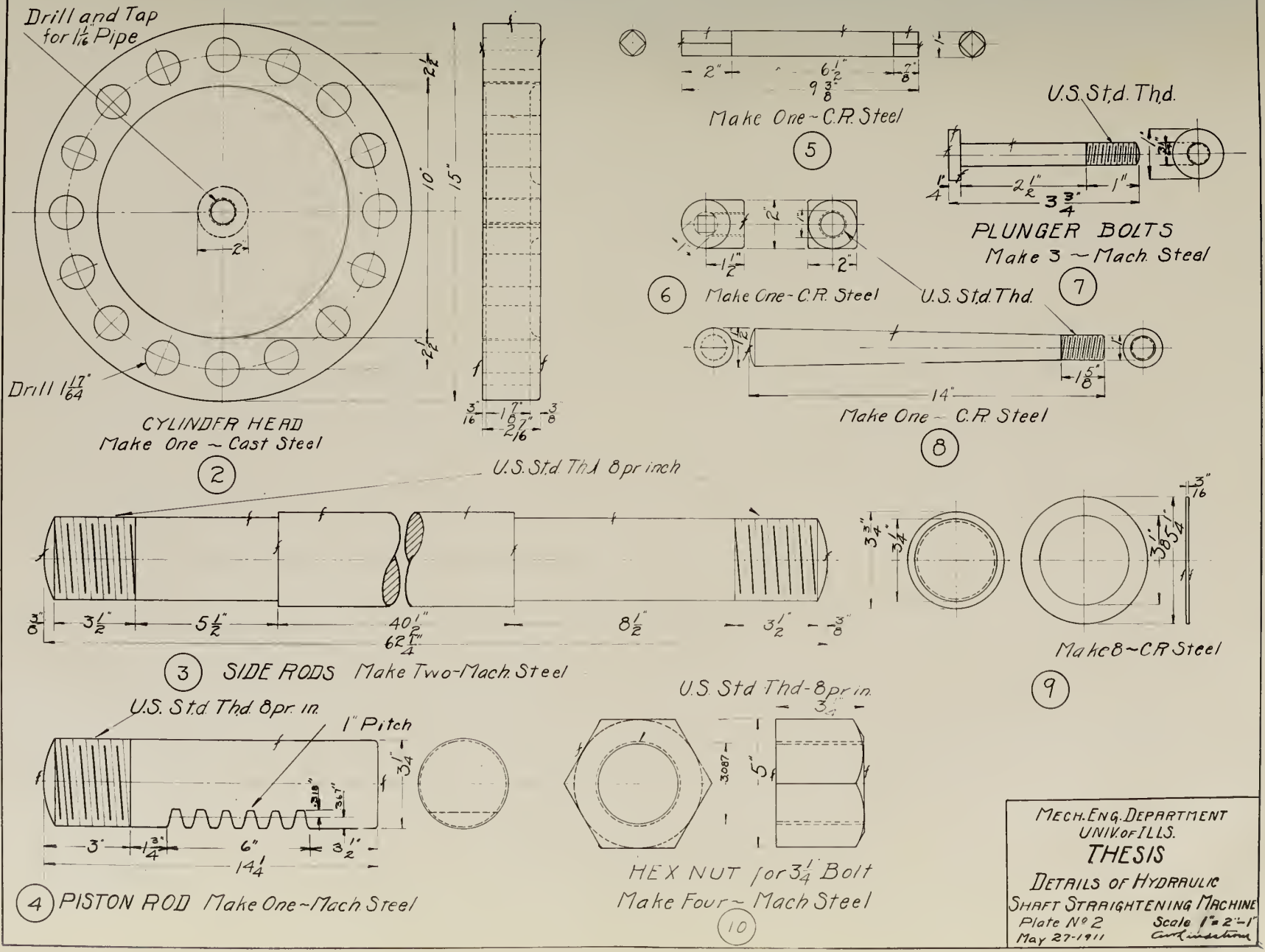
5 feet 0 inches

M = 75000 x 30 = 2,225,000 inch pounds

$\frac{M}{S} = \frac{I}{c} = \frac{2,225,000}{2 \times 16000} = 70.3$

$\frac{I}{c}$ = 70.3 for 15"-70 lb. special or 18"-70 lb. standard. Use 15"-70 lb. special *I beam*


MECH.ENG. DEPARTMENT
UNIV. OF ILLS.
THESIS
ASSEMBLY OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
PLATE NO. 1 Scale 1"=1'
MAY 27-1911
14"
11'-7"
12'-2"
3'-2½"
22"
27½"
21"


Drill and Tap for 1 1/16" Pipe
Drill 1 17/64"
CYLINDER HEAD
Make One ~ Cast Steel
(2)
Make One ~ C.R. Steel
(5)
U.S. St.d. Thd.
PLUNGER BOLTS
Make 3 ~ Mach. Steel
(7)
(6) Make One ~ C.R. Steel
U.S. St.d. Thd.
Make One ~ C.R. Steel
(8)
U.S. St.d. Thd. 8 pr inch
(3) SIDE RODS Make Two ~ Mach. Steel
Make 8 ~ C.R. Steel
(9)
U.S. St.d. Thd. 8 pr. in.
1" Pitch
(4) PISTON ROD Make One ~ Mach Steel
U.S. Std Thd - 8 pr in.
HEX NUT for 3 1/4" Bolt
Make Four ~ Mach Steel
(10)
MECH. ENG. DEPARTMENT
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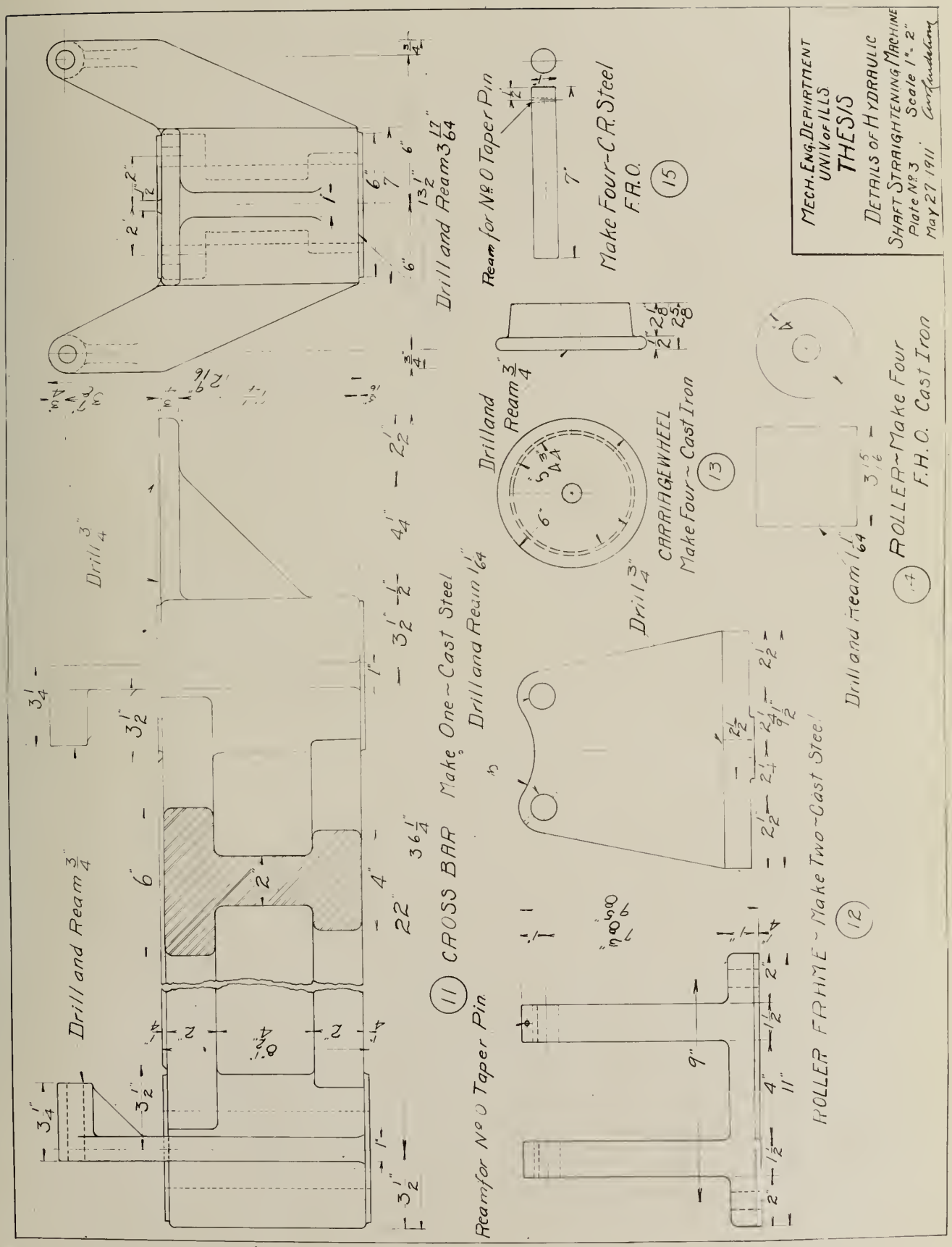
THESIS
DETAILS OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
Plate No 2
Scale 1" = 2'-1"
May 27-1911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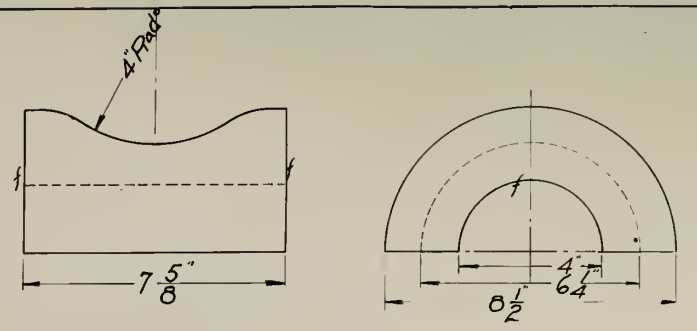
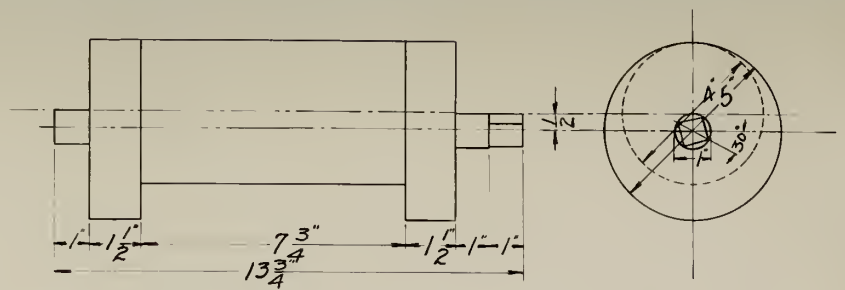
THESIS
DETAILS OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
Plate No. 3 Scale 1" = 2"
May 27 1911 Graduating
(11) CROSS BAR Make One ~ Cast Steel
Drill and Ream 3/4"
Ream for No. 0 Taper Pin
Drill 3/4"
Drill and Ream 1/64"
(12) ROLLER FRAME ~ Make Two ~ Cast Steel
Drill and Ream 1/64"
(13) CARRIAGE WHEEL Make Four ~ Cast Iron
Drill and Ream 3/4"
Ream for No. 0 Taper Pin
(15) Make Four ~ C.R. Steel F.H.O.
(17) ROLLER ~ Make Four F.H.O. Cast Iron



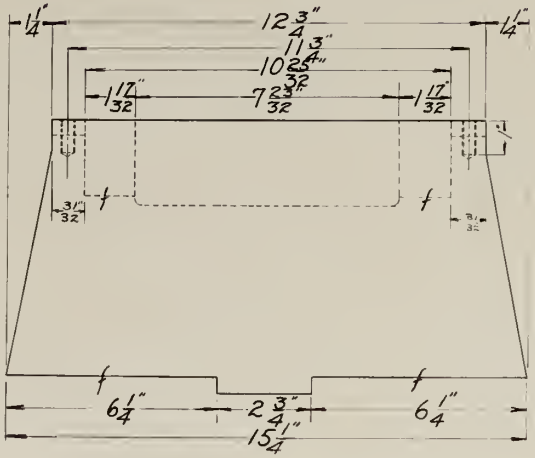
SUPPORT PAD Make Two ~ Cast Steel

(16)



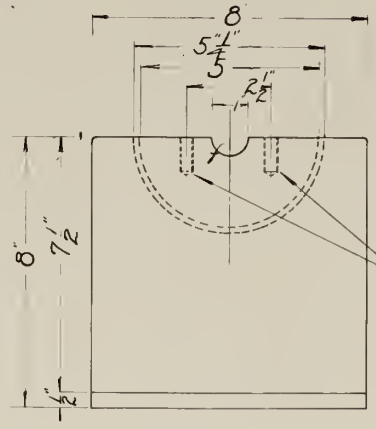
SUPPORT PIN Make Two ~ Mach. Steel F.R.O.

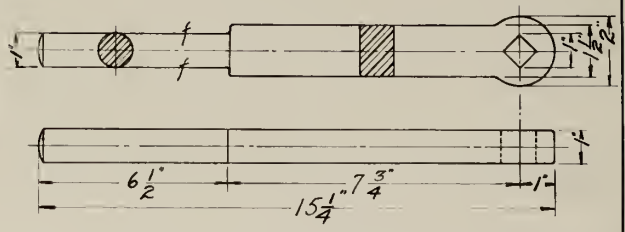
(18)



SUPPORT FRAMES
Make Two ~ Cast Iron

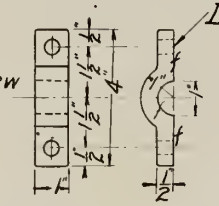
(17)





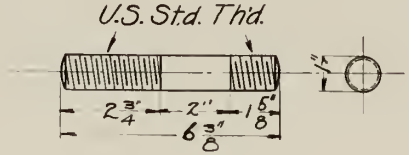
(19) SUPPORT HANDLE Make Two ~ Wrought Iron

Drill and Tap for 3/8" Cap Screw



Make Four ~ Cast Steel

(20)



CYLINDER STUDS
Make 16 ~ Mach Steel

(21)

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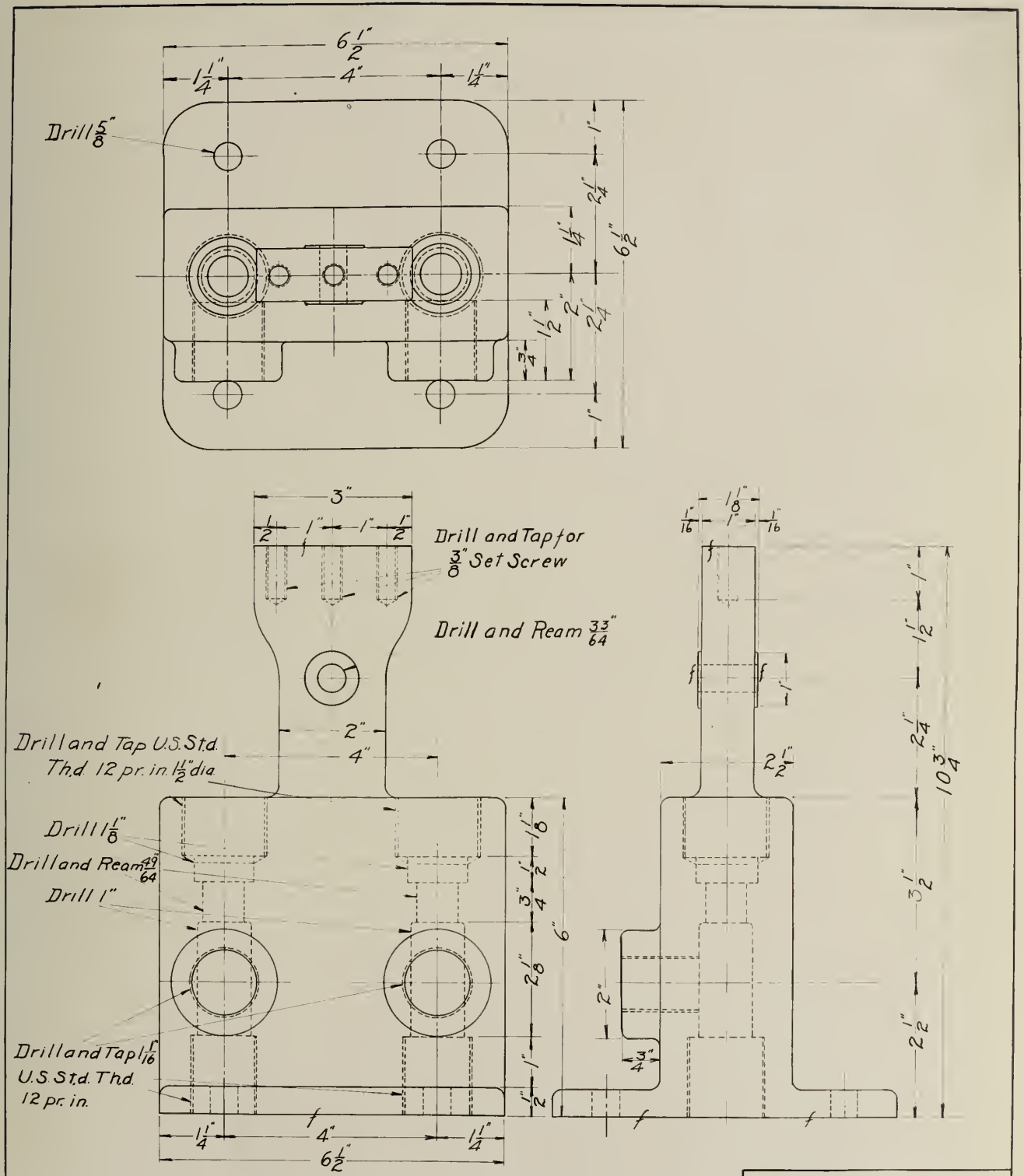
DETAILS OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
Plate No. 4 Scale 1" = 2"
May 27-1911 Arbindstone



PUMP BODY

Make One – Cast Steel

(22)

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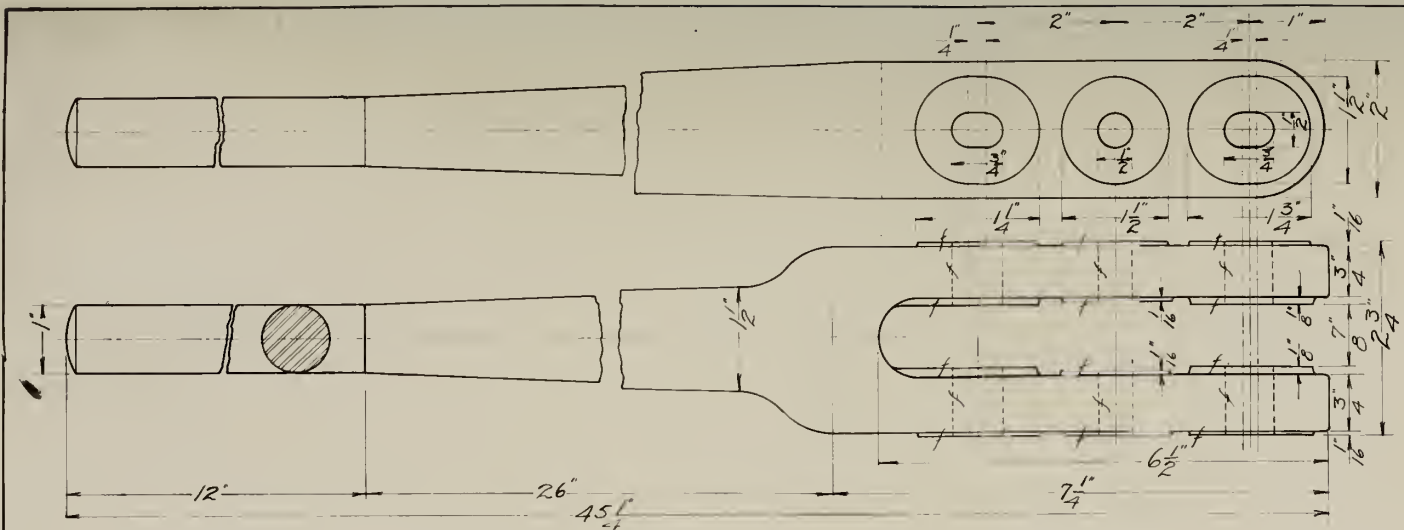
THESIS

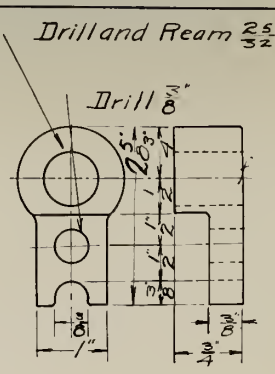
DETAILS OF HYDRAULIC SHAFT STRAIGHTENING MACHINE

Plate No. 5 Scale 1" = 1"

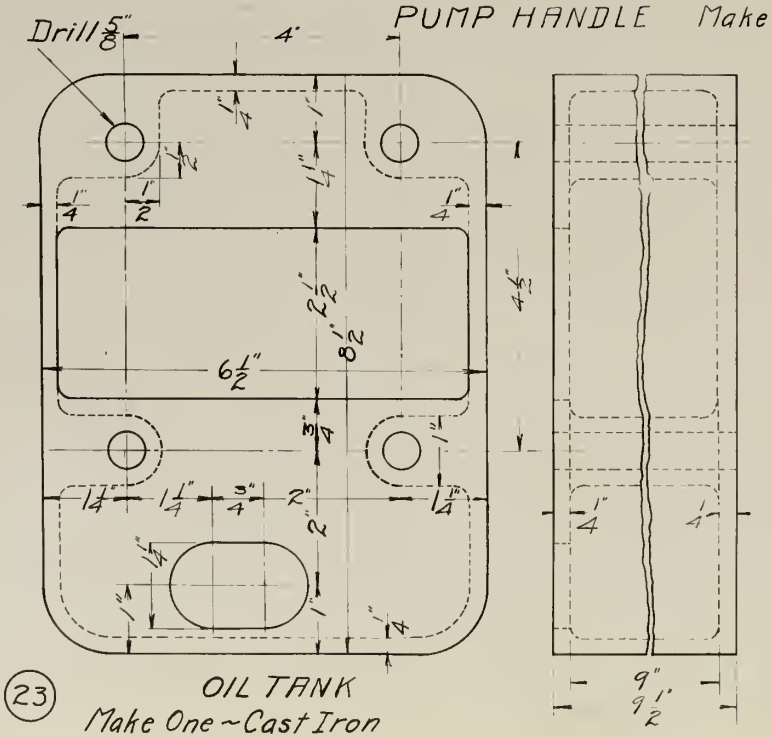
MAY 27 - 1911



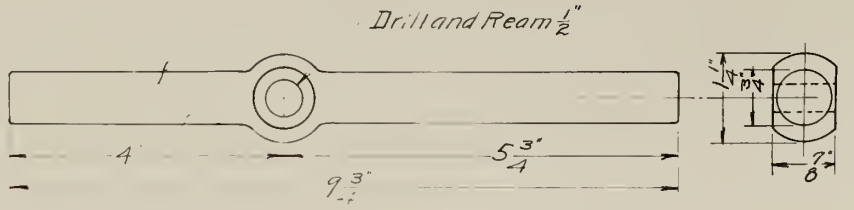
PUMP HANDLE Make One ~ Cast Steel (24)



PLUNGER GUIDE
Make Two-Cast Steel
(25)

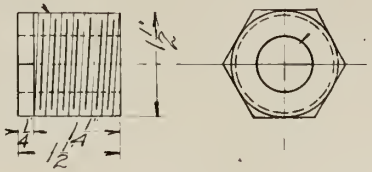


(23) OIL TANK
Make One ~ Cast Iron



(26) PUMP PLUNGER Make Two-C.R. Steel

U.S. Std. Thd. 12 pr. in. Drill and Ream 49/64"



PLUNGER BUSHING
Make Two ~ Brass
(27)

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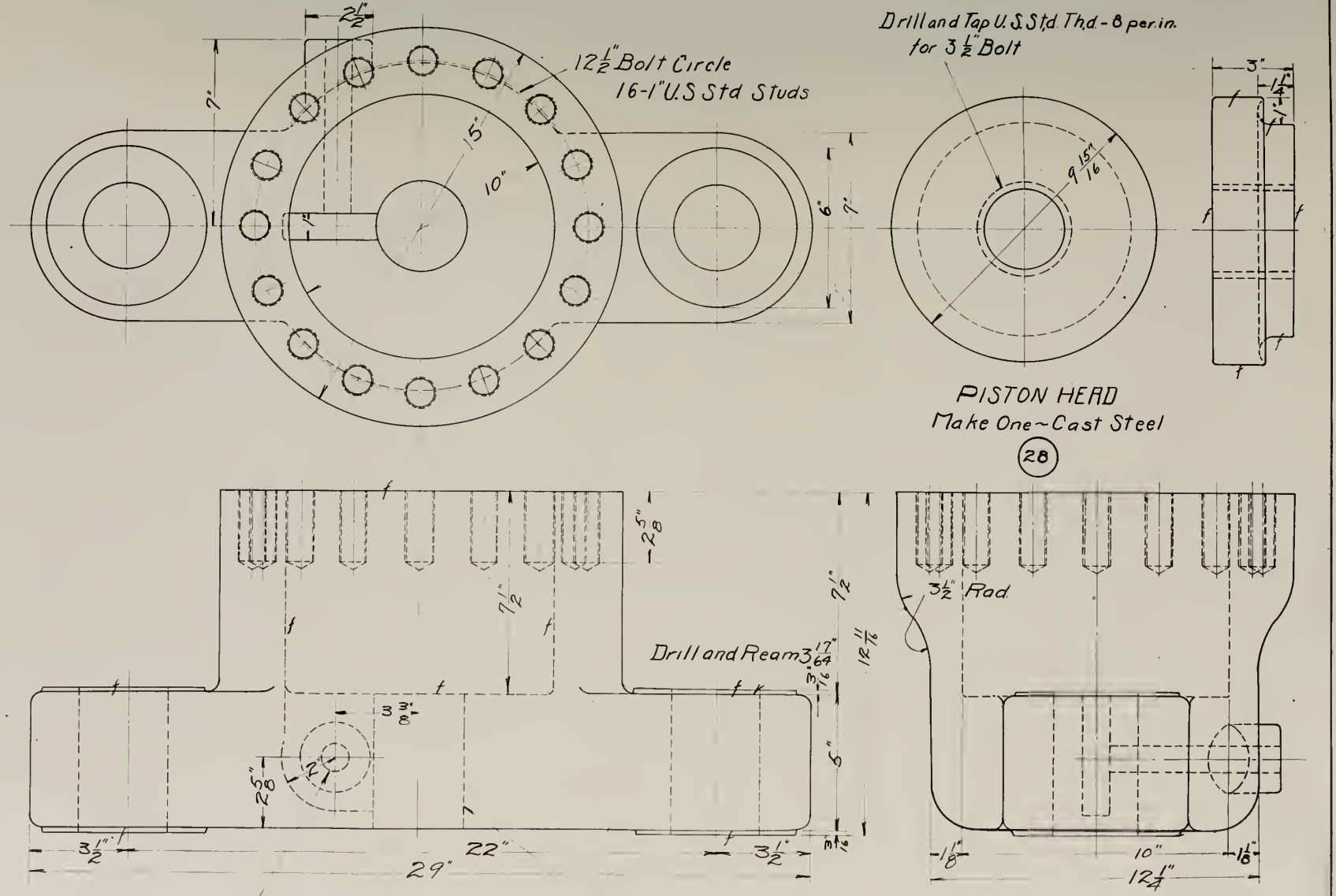
DETAILS OF HYDRAULIC SHAFT STRAIGHTENING MACHINE
Plate No. 6 Scale 1"=1"
May 27-1911


12½" Bolt Circle
16-1" U.S Std Studs
Drill and Tap U.S. Std. Thd. - 8 per in.
for 3½" Bolt
PISTON HEAD
Make One ~ Cast Steel
28
Drill and Ream 3 17/64"
3½" Rad
Drill and Ream 1 1/64"
MAIN CYLINDER
Make One ~ Cast Steel
1
Drill and Ream 3 23/64"
MECH. ENG. DEPARTMENT
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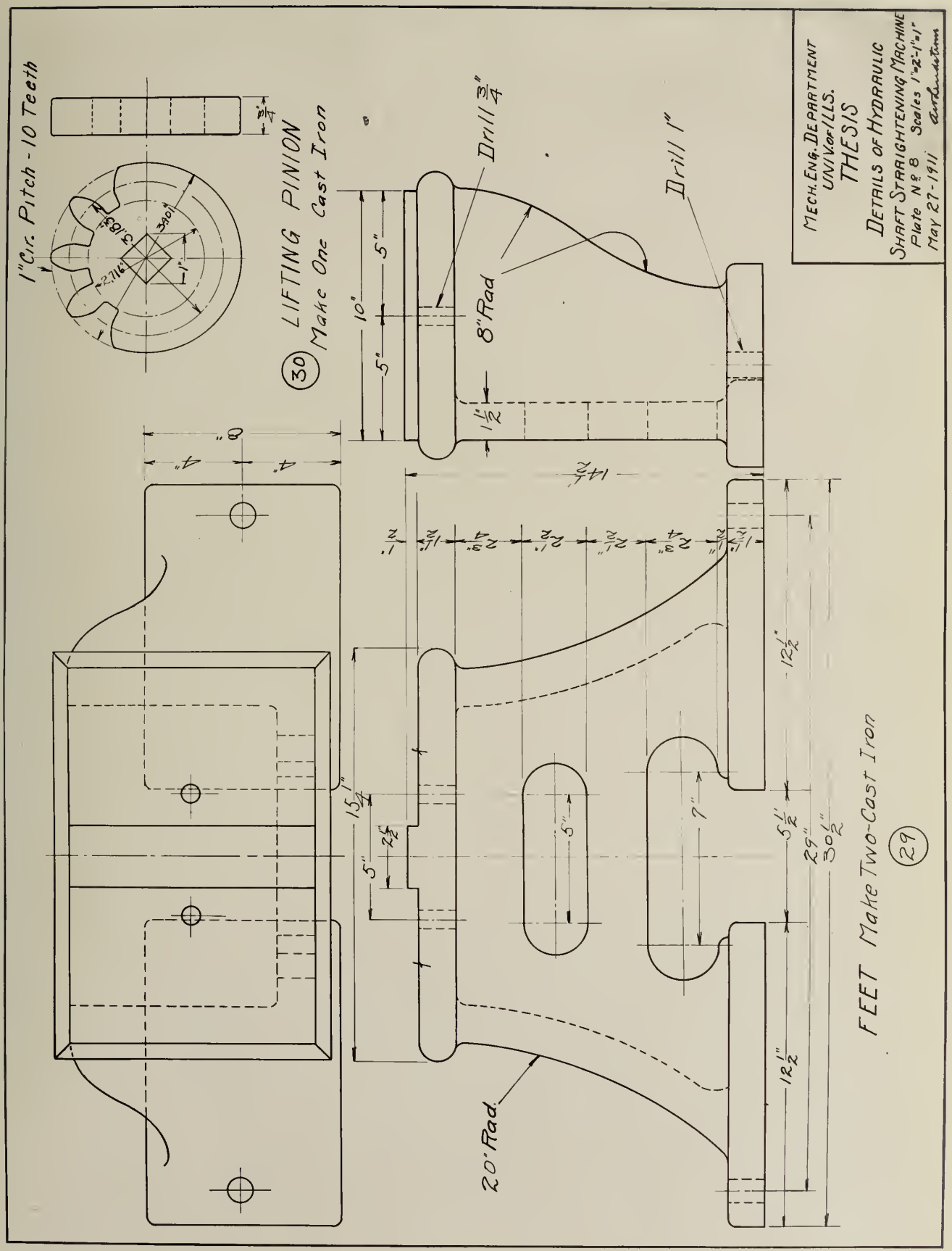
THESIS
DETAILS OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
Plate No 7
Scale 1" = 2"
May 27-1911
Carlinderstrom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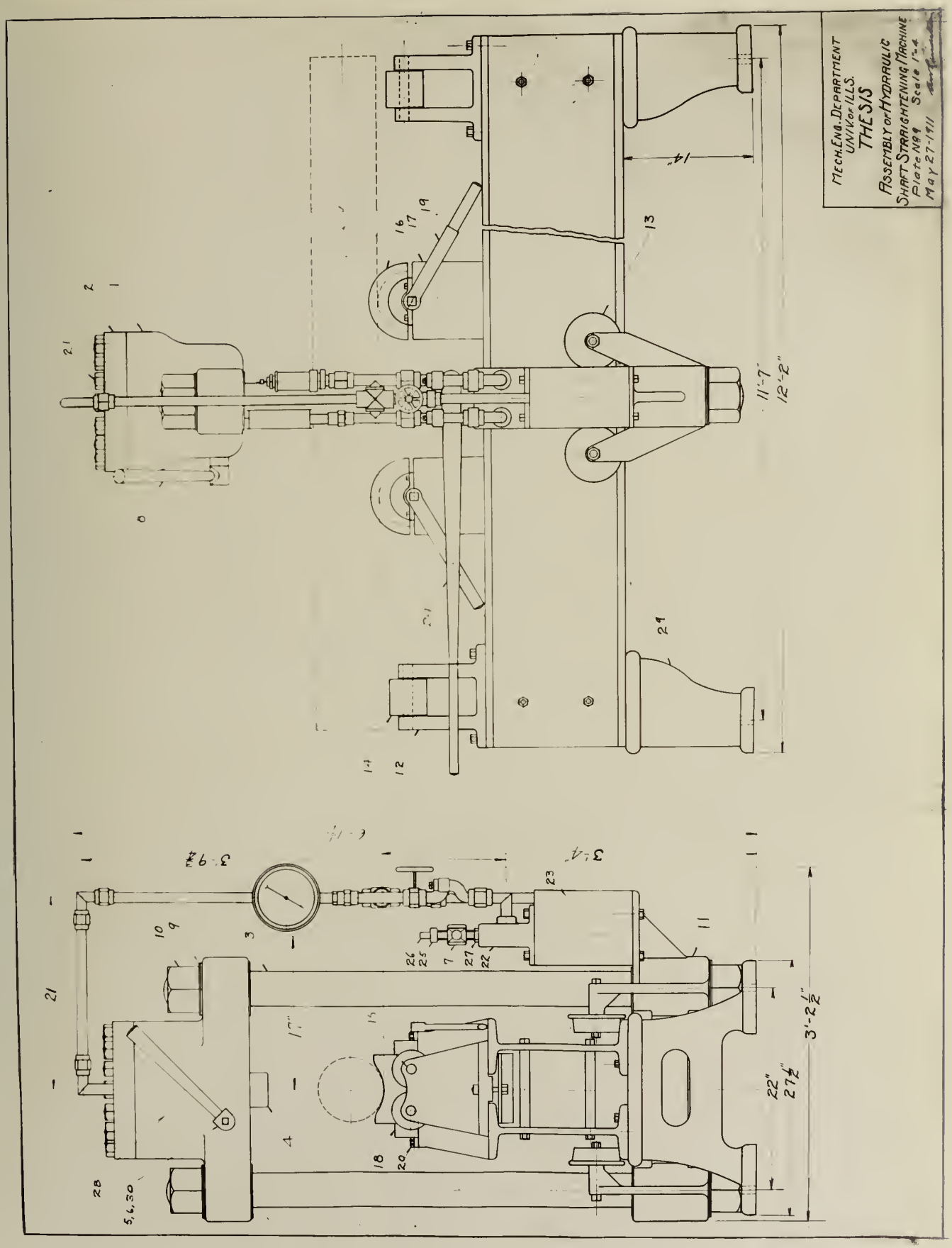
THESIS
DETAILS OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
Plate No 8 Scales 1"=1'-1"=1"
May 27-1911 Graduation
(30) LIFTING PINION
Make One Cast Iron
1" Cir. Pitch - 10 Teeth
Drill 3/4"
Drill 1"
8" Rad
20' Rad.
FEET Make Two-Cast Iron
(29)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THESIS
ASSEMBLY OF HYDRAULIC
SHAFT STRAIGHTENING MACHINE
PLATE No 9 Scale 1"=1'
May 27-1911
11'-7"
12'-2"
3'-2½"
22"
27½"

Bill of Material

Piece No.	Name	Material	Number Wanted	Plate No.
1	Main Cylinder	Cast Steel	1	7
2	Cylinder Head	" "	1	2
3	Side Rod	Machine Steel	2	2
4	Piston Rod	" "	1	2
5	Handle	Cold Rolled Steel	1	2
6		" " "	1	2
7	Pump Bolt	Machine Steel	3	2
8		Cold Rolled Steel	1	2
9	Washer	" " "	8	2
10	Hexagonal Nut	Machine Steel	4	2
11	Cross Bar	Cast Steel	1	3
12	Roller Frame	" "	2	3
13	Carriage Wheel	Cast Iron	4	3
14	Roller	" "	4	3
15	Roller Pin	Cold Rolled Steel	4	3
16	Support Pad	Cast Steel	2	4
17	Support Frame	Cast Iron	2	4
18	Support Pin	Machine Steel	2	4
19	Handle	Wrought Iron	2	4
20	Support Bearing Cap	Cast Steel	4	4
21	Stud Bolt	Machine Steel	16	4
22	Pump Body	Cast Steel	1	5
23	Oil Tank	Cast Iron	1	6

Bill of Material-cont.

Piece No.	Name	Material	Number Wanted	Plate No.
24	Pump Handle	Cast Steel	1	6
25	Plunger Guide	" "	2	6
26	Pump Plunger	Cold Rolled Steel	2	6
27	Plunger Bushing	Brass	2	6
28	Piston Head	Cast Steel	1	7
29	Feet	Cast Iron	2	8
30	Lifting Pinion	" "	1	8

Stock List

Name	Number Wanted	Size	Remarks
Vertical Check Valve	4	3/4"	Outside Thread
Stop Valve	1	3/4"	" "
Bronze Coupling	9		For 3/4" pipe
Bronze Elbow	1	6" x 3"	" " "
" "	2	4" x 3"	" " "
" "	1	3" x 3"	" " "
Hydraulic Pipe	7 ft.	3/4"	
Steel Cross	1	4" x 2 3/4"	Inside Thread for 3/4" pipe
Machine Bolt with nuts	4	3/4" x 5"	Finished
" " " "	4	1/2"x 12"	Rough
" " " "	4	1/2"x 10"	"
" " " "	4	1/2" x 2"	"
" " " "	4	3/4" x 3"	"
Hexagonal Nuts	16	1"	U.S. Std. Thd.
Cap Screws	11	3/8" x 1"	
I-Beams	2	15"-70#- 12 ft. long	
U-Packing	1	10" Outside Diameter	
Flange Packing	1	3/4" Inside Diameter	
Hydraulic Gauge	1		With Safety Valve
Spring Weighted Safety Valve	1	2000 #/sq.in.	
Bronze-T	2	7" x 1 1/2"	For 3/4"pipe